

NBSIR 74-462

Interlaboratory Comparisons of Static Force Calibrations

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Engineering Mechanics Section
Mechanics Division
Institute for Basic Standards
National Bureau of Standards
Washington, D. C. 20234

June 1974

Summary Report
Covering Period 7/15/71 to 12/31/73

Prepared for

**Department of Defense
Calibration Coordination Group
Working Group on Mass and Pressure
Project No. 72-61**

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

Interlaboratory Comparisons of Static Force Calibrations

1. SCOPE

This report covers phase I of a program of interlaboratory comparisons of static force calibrations developed for the Calibration Coordination group of the Department of Defense. The objective of the program is to allow each participating laboratory to examine the quality of its force calibration capabilities. Phase I includes force measurements up to 20,000 lbf.

2. TEST PROCEDURE

Four force measuring devices were circulated to each of the five participating laboratories. Each was asked to perform calibrations in both tension and compression at, as nearly as possible, ten specified loads over the range of each device. Procedures normally employed by each laboratory were to be used. The devices were divided into two groups, each routed through the laboratories in a different order. All devices were calibrated at the National Bureau of Standards before distribution and again at the termination of the routing. The two groups of devices consisted of the following:

Group A One 2,000-lbf capacity proving ring
 One 20,000-lbf capacity proving ring

Group B One 2,000-lbf capacity load cell
 One 20,000-lbf capacity load cell
 One electronic readout

Both groups of devices were to be calibrated over the same ranges. All laboratories used the same span setting for the load cell system.

3. DATA REDUCTION

The original data for all calibrations were transmitted to the National Bureau of Standards. All data for the proving ring calibrations were corrected to 23 °C. No corrections were applied to the load cell data. Second degree equations, with the load as the independent variable, were fitted to the average load readings from each laboratory using the method of least squares. The initial NBS calibration curves were selected as the base for comparison with the curves fitted to the individual laboratory data. To permit comparisons between devices, all curves were normalized using the initial NBS value at the maximum load (2,000 lbf or 20,000 lbf) as an arbitrary reference. Points on the individual curves corresponding to the nominal calibration loads are expressed as a percentage of the reference base.

4. SUMMARY OF RESULTS

The values from the curves fitted to the primary data, the corresponding normalized values, and the normalized differences from the first-NBS calibration are given in Tables 1 through 8. Standard deviations and curve coefficients for each calibration curve are presented in Table 9. Figures 1 through 6 show comparisons of normalized calibration curves against the initial NBS calibration curves. Two laboratories, A and D, did not calibrate any of the devices in tension.

With the exception of Laboratory C's tension calibration of the 2,000-lbf proving ring, all calibrations agreed to within 0.1 percent of capacity of the reference series of calibrations. There is evidence in Figure 6 that the 2,000-lbf proving ring showed a marked increase in short-term non-linearity during the series of calibrations. This is also suggested by the change in standard deviation in compression shown in Table 9. The small load cell appears to have a uniform change in output increasing to about 0.05 percent at capacity, with respect to the First-NBS calibration. The two 20,000-lbf devices show only insignificant changes.

5. CONCLUSIONS

In general, the intercomparison of data for the 2,000-lbf to 20,000-lbf range agreed to within acceptable limits. The intercomparison of data for the 200-lbf to 2,000-lbf range was inconclusive due to the apparent instability of the test devices being calibrated. Although no serious problem areas were apparent from the data furnished by the various laboratories, there was no basis for evaluation of tension calibration capabilities of the two laboratories that did not supply tension calibration data.

Comparison of the results was complicated by factors such as non-uniformity of test procedures, variations in methods of reporting results, and apparent instability of at least one of the test devices. Information about these factors was obtained that will be useful in planning further tests, but a more comprehensive analysis of the current data did not seem to be justified.

6. RECOMMENDATIONS FOR FUTURE TESTS

If this program is continued, consideration should be given to the following:

1. Greater or smaller load ranges
2. More stable test devices
3. Frequent checks by NBS of instrument stability during laboratory circuit

4. Use of a uniform calibration procedure
5. Full and/or expanded participation of interested laboratories.

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 1 - CALIBRATION DATA FOR 23 DEGREES C

2,000 LBF MOREHOUSE PROVING RING NO. 144

COMPRESSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
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SECOND-DEGREE CURVE VALUES

200.	58.10	58.22	58.09	58.11	58.23	58.26	58.43
400.	116.58	116.69	116.57	116.64	116.74	116.77	116.88
600.	175.45	175.55	175.46	175.57	175.65	175.67	175.73
800.	234.74	234.81	234.74	234.90	234.97	234.96	234.98
1000.	294.43	294.48	294.42	294.63	294.70	294.65	294.64
1200.	354.53	354.54	354.49	354.77	354.84	354.74	354.71
1400.	415.03	415.01	414.97	415.31	415.38	415.22	415.18
1600.	475.95	475.87	475.84	476.24	476.33	476.09	476.06
1800.	537.26	537.13	537.11	537.58	537.69	537.37	537.34
2000.	598.99	598.80	598.78	599.32	599.46	599.03	599.02

NORMALIZED CURVE VALUES

200.	9.700	9.720	9.698	9.701	9.722	9.726	9.755
400.	19.462	19.480	19.461	19.472	19.490	19.494	19.512
600.	29.292	29.308	29.293	29.311	29.325	29.327	29.337
800.	39.189	39.202	39.189	39.216	39.228	39.226	39.230
1000.	49.155	49.162	49.153	49.189	49.200	49.191	49.190
1200.	59.188	59.190	59.181	59.228	59.239	59.223	59.218
1400.	69.289	69.284	69.278	69.334	69.347	69.320	69.313
1600.	79.458	79.445	79.441	79.508	79.523	79.483	79.477
1800.	89.695	89.673	89.669	89.748	89.766	89.712	89.707
2000.	100.000	99.968	99.965	100.056	100.078	100.007	100.005

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

200.	.000	.019	-.002	.000	.022	.026	.055
400.	.000	.018	-.001	.010	.027	.032	.050
600.	.000	.016	.001	.019	.033	.035	.046
800.	.000	.012	.000	.027	.039	.037	.041
1000.	.000	.008	-.002	.034	.045	.037	.036
1200.	.000	.002	-.007	.040	.051	.035	.030
1400.	.000	-.005	-.011	.045	.058	.031	.024
1600.	.000	-.013	-.018	.050	.064	.025	.018
1800.	.000	-.022	-.026	.053	.071	.017	.012
2000.	.000	-.032	-.035	.056	.078	.007	.005

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 2 - CALIBRATION DATA FOR 23 DEGREES C

2,000 LRF MOREHOUSE PROVING RING NO. 144

TENSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
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SECOND-DEGREE CURVE VALUES

200.	57.64		57.67	57.70		57.34	57.50
400.	114.96		114.97	115.07		114.68	114.83
600.	171.92		171.91	172.09		171.67	171.81
800.	228.53		228.49	228.75		228.31	228.44
1000.	284.78		284.71	285.07		284.60	284.71
1200.	340.67		340.57	341.04		340.54	340.64
1400.	396.21		396.06	396.66		396.13	396.21
1600.	451.39		451.20	451.93		451.37	451.44
1800.	506.22		505.97	506.85		506.26	506.31
2000.	560.69		560.39	561.43		560.80	560.83

NORMALIZED CURVE VALUES

200.	10.281		10.286	10.292		10.226	10.255
400.	20.504		20.505	20.523		20.453	20.480
600.	30.663		30.661	30.692		30.618	30.642
800.	40.759		40.752	40.799		40.720	40.742
1000.	50.791		50.779	50.843		50.760	50.779
1200.	60.760		60.742	60.826		60.737	60.754
1400.	70.665		70.638	70.746		70.652	70.666
1600.	80.507		80.473	80.603		80.503	80.515
1800.	90.285		90.241	90.399		90.293	90.301
2000.	100.000		99.947	100.132		100.019	100.025

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

200.	.000		.005	.011		-.055	-.026
400.	.000		.001	.019		-.051	-.024
600.	.000		-.003	.029		-.045	-.021
800.	.000		-.007	.040		-.039	-.017
1000.	.000		-.012	.052		-.031	-.012
1200.	.000		-.018	.066		-.023	-.006
1400.	.000		-.027	.080		-.014	.001
1600.	.000		-.034	.096		-.004	.008
1800.	.000		-.044	.113		.007	.016
2000.	.000		-.053	.132		.019	.025

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 3 - CALIBRATION DATA FOR 23 DEGREES C

2,000 LRF BLH LOAD CELL NO. 51841

COMPRESSION

LOAD LRF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
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SECOND-DEGREE CURVE VALUES

200.	4727.	4733.	4726.	4731.	4716.	4728.	4730.
400.	9457.	9460.	9454.	9462.	9449.	9456.	9458.
600.	14187.	14187.	14183.	14193.	14183.	14183.	14187.
800.	18918.	18915.	18911.	18925.	18918.	18910.	18915.
1000.	23649.	23644.	23640.	23657.	23653.	23638.	23644.
1200.	28380.	28373.	28370.	28390.	28389.	28366.	28373.
1400.	33113.	33102.	33099.	33123.	33125.	33095.	33102.
1600.	37845.	37832.	37829.	37856.	37863.	37823.	37831.
1800.	42578.	42563.	42559.	42589.	42601.	42552.	42561.
2000.	47312.	47294.	47289.	47323.	47339.	47281.	47291.

NORMALIZED CURVE VALUES

200.	9.992	10.005	9.989	9.999	9.967	9.994	9.998
400.	19.989	19.995	19.982	19.999	19.972	19.986	19.991
600.	29.987	29.987	29.978	30.000	29.978	29.978	29.985
800.	39.985	39.980	39.971	40.001	39.985	39.970	39.980
1000.	49.985	49.974	49.967	50.003	49.994	49.963	49.974
1200.	59.986	59.970	59.964	60.006	60.004	59.956	59.970
1400.	69.988	69.966	69.959	70.009	70.015	69.950	69.966
1600.	79.991	79.964	79.957	80.013	80.028	79.944	79.962
1800.	89.995	89.963	89.955	90.018	90.043	89.939	89.959
2000.	100.000	99.963	99.952	100.024	100.059	99.935	99.956

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

200.	.000	.013	-.003	.007	-.025	.002	.006
400.	.000	.007	-.006	.010	-.017	-.003	.003
600.	.000	.001	-.009	.013	-.009	-.009	-.001
800.	.000	-.005	-.014	.016	-.000	-.015	-.006
1000.	.000	-.011	-.019	.018	.008	-.023	-.011
1200.	.000	-.017	-.022	.020	.018	-.030	-.016
1400.	.000	-.022	-.029	.021	.027	-.038	-.022
1600.	.000	-.027	-.034	.022	.037	-.047	-.029
1800.	.000	-.032	-.040	.023	.048	-.056	-.036
2000.	.000	-.037	-.048	.024	.059	-.065	-.044

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 4 - CALIBRATION DATA FOR 23 DEGREES C

2,000 LBF RLH LOAD CELL NO. 51841

TENSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
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SECOND-DEGREE CURVE VALUES

200.	4734.	4729.	4731.	4731.	4734.
400.	9463.	9455.	9460.	9458.	9462.
600.	14190.	14178.	14187.	14183.	14187.
800.	18916.	18900.	18913.	18906.	18910.
1000.	23640.	23620.	23637.	23627.	23631.
1200.	28361.	28339.	28360.	28345.	28349.
1400.	33081.	33055.	33081.	33061.	33066.
1600.	37799.	37770.	37801.	37775.	37780.
1800.	42515.	42483.	42519.	42487.	42493.
2000.	47229.	47194.	47235.	47197.	47203.

NORMALIZED CURVE VALUES

200.	10.023	10.013	10.018	10.016	10.024
400.	20.036	20.019	20.030	20.025	20.034
600.	30.046	30.019	30.039	30.030	30.038
800.	40.051	40.017	40.045	40.030	40.038
1000.	50.053	50.011	50.047	50.025	50.034
1200.	60.050	60.003	60.047	60.016	60.025
1400.	70.044	69.988	70.043	70.002	70.012
1600.	80.033	79.971	80.036	79.983	79.994
1800.	90.019	89.950	90.026	89.960	89.971
2000.	100.000	99.925	100.013	99.931	99.944

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

200.	.000	-.010	-.004	-.007	.002
400.	.000	-.017	-.006	-.011	-.003
600.	.000	-.026	-.007	-.016	-.007
800.	.000	-.034	-.007	-.021	-.013
1000.	.000	-.042	-.006	-.028	-.019
1200.	.000	-.047	-.004	-.035	-.025
1400.	.000	-.056	-.001	-.042	-.032
1600.	.000	-.062	.003	-.050	-.040
1800.	.000	-.068	.007	-.059	-.048
2000.	.000	-.075	.013	-.069	-.056

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 5 - CALIBRATION DATA FOR 23 DEGREES C

20,000 LBF MOREHOUSE PROVING RING NO. 193

COMPRESSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
SECOND-DEGREE CURVE VALUES							
2000.	92.63	92.82	92.85	92.66	92.57	92.51	92.65
4000.	185.57	185.70	185.66	185.68	185.40	185.45	185.58
6000.	278.86	278.95	278.85	279.06	278.62	278.74	278.87
8000.	372.51	372.58	372.42	372.80	372.23	372.40	372.52
10000.	466.52	466.57	466.38	466.89	466.22	466.42	466.53
12000.	560.89	560.94	560.73	561.35	560.60	560.81	560.89
14000.	655.61	655.69	655.46	656.16	655.37	655.55	655.61
16000.	750.69	750.80	750.57	751.33	750.52	750.66	750.69
18000.	846.13	846.29	846.07	846.86	846.07	846.12	846.13
20000.	941.92	942.15	941.95	942.75	942.00	941.96	941.93

NORMALIZED CURVE VALUES							
2000.	9.834	9.854	9.858	9.837	9.828	9.822	9.836
4000.	19.701	19.715	19.711	19.713	19.683	19.688	19.702
6000.	29.606	29.615	29.604	29.627	29.580	29.593	29.607
8000.	39.548	39.555	39.538	39.579	39.518	39.536	39.549
10000.	49.529	49.534	49.514	49.568	49.497	49.518	49.529
12000.	59.547	59.553	59.531	59.596	59.517	59.539	59.548
14000.	69.604	69.612	69.588	69.662	69.578	69.597	69.604
16000.	79.698	79.710	79.685	79.766	79.680	79.694	79.698
18000.	89.830	89.847	89.824	89.908	89.824	89.830	89.831
20000.	100.000	100.024	100.003	100.088	100.008	100.004	100.001

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION							
2000.	.000	.020	.023	.003	-.006	-.012	.002
4000.	.000	.014	.010	.012	-.018	-.013	.001
6000.	.000	.009	-.001	.021	-.026	-.013	.001
8000.	.000	.007	-.010	.030	-.030	-.012	.001
10000.	.000	.005	-.015	.039	-.032	-.011	.001
12000.	.000	.006	-.017	.049	-.030	-.009	.000
14000.	.000	.008	-.016	.059	-.026	-.006	.000
16000.	.000	.012	-.013	.068	-.018	-.004	.000
18000.	.000	.017	-.006	.078	-.006	-.000	.001
20000.	.000	.024	.003	.088	.008	.004	.001

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 6 - CALIBRATION DATA FOR 23 DEGREES C

20,000 LBF MOREHOUSE PROVING RING NO. 193

TENSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
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SECOND-DEGREE CURVE VALUES

2000.	92.18		92.06	92.18		92.18	92.14
4000.	184.02		183.85	184.10		184.05	184.00
6000.	275.54		275.33	275.70		275.60	275.53
8000.	366.75		366.50	366.97		366.82	366.75
10000.	457.64		457.36	457.93		457.72	457.64
12000.	548.21		547.90	548.56		548.30	548.21
14000.	638.47		638.13	638.87		638.55	638.47
16000.	728.41		728.05	728.86		728.48	728.40
18000.	818.04		817.65	818.53		818.08	818.01
20000.	907.34		906.95	907.88		907.36	907.30

NORMALIZED CURVE VALUES

2000.	10.159		10.146	10.159		10.159	10.155
4000.	20.281		20.262	20.290		20.285	20.279
6000.	30.368		30.345	30.385		30.374	30.367
8000.	40.420		40.393	40.445		40.428	40.420
10000.	50.437		50.406	50.469		50.447	50.437
12000.	60.420		60.385	60.458		60.429	60.420
14000.	70.367		70.329	70.411		70.376	70.367
16000.	80.280		80.240	80.329		80.287	80.278
18000.	90.157		90.115	90.212		90.162	90.154
20000.	100.000		99.957	100.059		100.001	99.995

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

2000.	.000		-.013	-.000		.000	-.004
4000.	.000		-.019	.009		.004	-.002
6000.	.000		-.023	.017		.007	-.001
8000.	.000		-.027	.025		.008	-.000
10000.	.000		-.031	.032		.009	.000
12000.	.000		-.035	.038		.009	.000
14000.	.000		-.038	.044		.009	-.000
16000.	.000		-.040	.050		.007	-.001
18000.	.000		-.043	.055		.005	-.003
20000.	.000		-.043	.059		.001	-.005

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 7 - CALIBRATION DATA FOR 23 DEGREES C

20,000 LRF BLH LOAD CELL NO. 82625

COMPRESSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
SECOND-DEGREE CURVE VALUES							
2000.	4769.	4775.	4766.	4772.	4763.	4765.	4773.
4000.	9530.	9540.	9525.	9537.	9518.	9528.	9536.
6000.	14285.	14300.	14280.	14297.	14270.	14285.	14294.
8000.	19036.	19054.	19030.	19051.	19017.	19036.	19046.
10000.	23781.	23803.	23774.	23799.	23760.	23781.	23793.
12000.	28521.	28547.	28514.	28541.	28500.	28520.	28534.
14000.	33256.	33285.	33249.	33278.	33235.	33253.	33271.
16000.	37985.	38018.	37979.	38010.	37967.	37979.	38001.
18000.	42709.	42746.	42703.	42736.	42694.	42700.	42727.
20000.	47429.	47468.	47423.	47456.	47418.	47414.	47447.

NORMALIZED CURVE VALUES

2000.	10.055	10.067	10.049	10.062	10.042	10.046	10.063
4000.	20.093	20.114	20.083	20.109	20.068	20.089	20.106
6000.	30.120	30.150	30.108	30.144	30.086	30.120	30.137
8000.	40.136	40.174	40.124	40.167	40.096	40.137	40.157
10000.	50.140	50.187	50.126	50.178	50.097	50.141	50.166
12000.	60.134	60.189	60.120	60.178	60.090	60.133	60.163
14000.	70.117	70.180	70.103	70.166	70.075	70.111	70.149
16000.	80.089	80.159	80.076	80.142	80.051	80.077	80.124
18000.	90.050	90.127	90.037	90.106	90.018	90.029	90.087
20000.	100.000	100.084	99.988	100.058	99.978	99.969	100.039

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

2000.	.000	.012	-.006	.007	-.013	-.009	.008
4000.	.000	.021	-.010	.016	-.025	-.003	.013
6000.	.000	.030	-.011	.024	-.033	-.000	.017
8000.	.000	.039	-.012	.031	-.040	.001	.022
10000.	.000	.047	-.014	.038	-.043	.001	.025
12000.	.000	.055	-.014	.043	-.044	-.002	.029
14000.	.000	.062	-.014	.048	-.043	-.006	.032
16000.	.000	.070	-.013	.052	-.038	-.012	.035
18000.	.000	.077	-.014	.056	-.032	-.021	.037
20000.	.000	.084	-.012	.058	-.022	-.031	.039

OMNITAB - COMPARISON WITH FIRST-NBS CALIBRATION

TABLE 8 - CALIBRATION DATA FOR 23 DEGREES C

20,000 LBF BLH LOAD CELL NO. 82625

TENSION

LOAD LBF	FIRST NBS	LAB A	LAB B	LAB C	LAB D	LAB E	FINAL NBS
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SECOND-DEGREE CURVE VALUES

2000.	4776.		4780.	4763.		4775.	4779.
4000.	9555.		9559.	9542.		9554.	9559.
6000.	14340.		14344.	14326.		14339.	14345.
8000.	19131.		19135.	19116.		19129.	19136.
10000.	23927.		23932.	23912.		23926.	23932.
12000.	28729.		28735.	28713.		28728.	28734.
14000.	33536.		33545.	33520.		33536.	33542.
16000.	38349.		38360.	38333.		38350.	38355.
18000.	43167.		43181.	43151.		43170.	43174.
20000.	47991.		48009.	47975.		47996.	47999.

NORMALIZED CURVE VALUES

2000.	9.952		9.960	9.925		9.949	9.959
4000.	19.911		19.918	19.883		19.907	19.919
6000.	29.881		29.889	29.852		29.878	29.890
8000.	39.863		39.872	39.833		39.860	39.873
10000.	49.857		49.867	49.826		49.855	49.868
12000.	59.862		59.876	59.830		59.861	59.874
14000.	69.879		69.898	69.847		69.880	69.892
16000.	79.908		79.931	79.875		79.911	79.922
18000.	89.948		89.977	89.915		89.954	89.963
20000.	100.000		100.037	99.967		100.010	100.016

NORMALIZED DIFFERENCES FROM FIRST-NBS CALIBRATION

2000.	.000		.008	-.027		-.003	.007
4000.	.000		.007	-.028		-.003	.008
6000.	.000		.008	-.029		-.004	.009
8000.	.000		.009	-.030		-.003	.010
10000.	.000		.011	-.031		-.002	.011
12000.	.000		.013	-.032		-.001	.012
14000.	.000		.019	-.032		.001	.013
16000.	.000		.024	-.033		.003	.014
18000.	.000		.029	-.033		.006	.015
20000.	.000		.037	-.033		.010	.016

Table 9 - Standard deviation (normalized for capacity deflection = 100)
of ten values relative to a fitted curve plotted to the equation:
Deflection = $A+B(\text{Load})+C(\text{Load})^2$; and the curve coefficients.

Laboratory	Normalized	Curve Coefficients		
	Std. Dev.	A	B	C
	2,000 lbf Proving Ring No. 144 in Compression			
NBS-1	0.0089	0.040	0.289308	5.083x10 ⁻⁶
A	0.0182	0.156	0.289323	4.998x10 ⁻⁶
B	0.0100	0.004	0.289432	4.979x10 ⁻⁶
C	0.0103	-0.022	0.289639	5.017x10 ⁻⁶
D	0.0113	0.137	0.289470	5.095x10 ⁻⁶
E	0.0184	0.151	0.289562	4.939x10 ⁻⁶
NBS-2	0.0193	0.392	0.289190	5.062x10 ⁻⁶
	2,000 lbf Proving Ring No. 144 in Tension			
NBS-1	0.0113	-0.029	0.289260	-4.451x10 ⁻⁶
A	-	-	-	-
B	0.0096	0.001	0.289222	-4.514x10 ⁻⁶
C	0.0113	-0.012	0.289450	-4.366x10 ⁻⁶
D	-	-	-	-
E	0.0220	-0.359	0.289350	-4.386x10 ⁻⁶
NBS-2	0.0111	-0.186	0.289291	-4.392x10 ⁻⁶

Table 9 - Standard deviation (normalized for capacity deflection = 100)
of ten values relative to a fitted curve plotted to the equation:
Deflection = A+B(Load)+C(Load)²; and the curve coefficients.

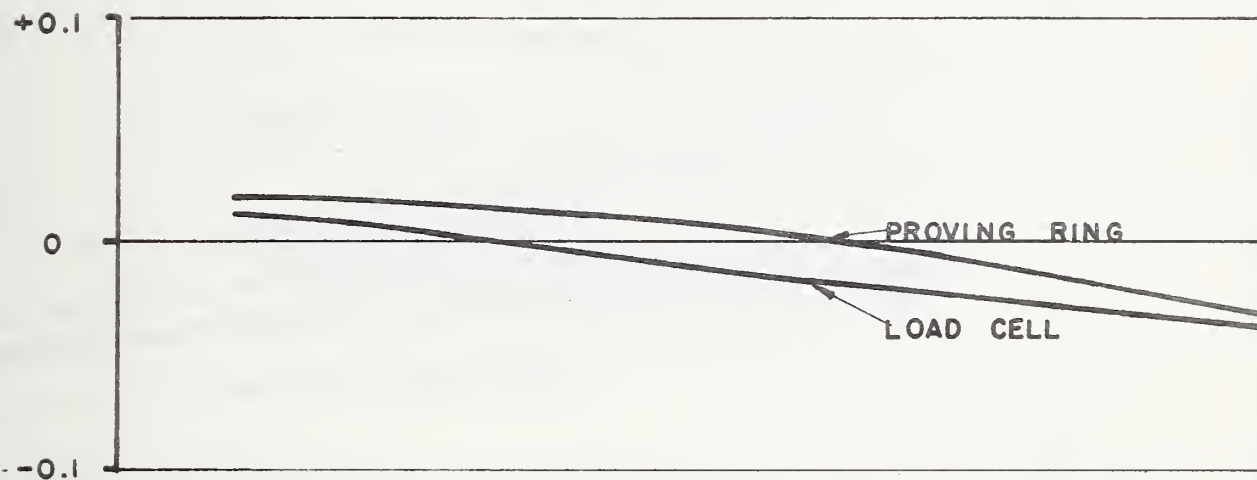
<u>Laboratory</u>	<u>Normalized Std. Dev.</u>	<u>Curve Coefficients</u>		
		<u>A</u>	<u>B</u>	<u>C</u>
2,000 lbf Load Cell No. 51841 in Compression				
NBS-1	0.0021	- 1.9	23.6449	6.0x10 ⁻⁶
A	0.0080	7.2	23.6295	7.0x10 ⁻⁶
B	0.0057	- 2.6	23.6404	4.1x10 ⁻⁶
C	0.0035	- 0.2	23.6534	4.1x10 ⁻⁶
D	0.0018	-17.1	23.6618	8.2x10 ⁻⁶
E	0.0039	1.6	23.6337	2.9x10 ⁻⁶
NBS-2	0.0012	2.5	23.6382	3.0x10 ⁻⁶
2,000 lbf Load Cell No. 51841 in Tension				
NBS-1	0.0017	2.4	23.6610	-23.8x10 ⁻⁶
A	-	-	-	-
B	0.0103	2.3	23.6401	-22.1x10 ⁻⁶
C	0.0024	1.4	23.6542	-18.6x10 ⁻⁶
D	-	-	-	-
E	0.0032	1.0	23.6531	-27.6x10 ⁻⁶
NBS-2	0.0032	4.9	23.6529	-27.0x10 ⁻⁶
20,000 lbf Proving Ring No. 193 in Compression				
NBS-1	0.0040	0.049	0.0462011	4.462x10 ⁻⁸
A	0.0074	0.308	0.0461612	4.653x10 ⁻⁸
B	0.0176	0.429	0.0461152	4.804x10 ⁻⁸
C	0.0051	-0.004	0.0462420	4.479x10 ⁻⁸
D	0.0107	0.125	0.0461257	4.839x10 ⁻⁸
E	0.0082	-0.059	0.0461956	4.526x10 ⁻⁸
NBS-2	0.0086	0.073	0.0461980	4.473x10 ⁻⁸

Table 9 - Standard deviation (normalized for capacity deflection = 100)
of ten values relative to a fitted curve plotted to the equation:
Deflection = $A+B(\text{Load})+C(\text{Load})^2$; and the curve coefficients.

<u>Laboratory</u>	<u>Normalized Std. Dev.</u>	<u>Curve Coefficients</u>		
		<u>A</u>	<u>B</u>	<u>C</u>
20,000 lbf Proving Ring No. 193 in Tension				
NBS-1	0.0073	0.022	0.0461574	-3.956x10 ⁻⁸
A	-	-	-	-
B	0.0058	-0.041	0.0461302	-3.904x10 ⁻⁸
C	0.0062	-0.066	0.0462015	-4.022x10 ⁻⁸
D	-	-	-	-
E	-0.0069	-0.016	0.0461794	-4.054x10 ⁻⁸
NBS-2	0.0083	-0.034	0.0461684	-4.009x10 ⁻⁸
20,000 lbf Load Cell No. 82625 in Compression				
NBS-1	0.0025	2.9	2.38431	-65.2x10 ⁻⁸
A	0.0065	4.4	2.38655	-66.8x10 ⁻⁸
B	0.0036	0.9	2.38359	-62.4x10 ⁻⁸
C	0.0018	1.5	2.386741	-70.1x10 ⁻⁸
D	0.0115	3.4	2.38067	-49.7x10 ⁻⁸
E	0.0039	-4.5	2.38622	-76.5x10 ⁻⁸
NBS-2	0.0018	4.0	2.38564	-67.5x10 ⁻⁸
20,000 lbf Load Cell No. 82625 in Tension				
NBS-1	0.0040	2.4	2.38546	69.9x10 ⁻⁸
A	-	-	-	-
B	0.0078	6.6	2.38499	75.6x10 ⁻⁸
C	0.0029	-9.8	2.38512	70.6x10 ⁻⁸
D	-	-	-	-
E	0.0037	1.4	2.38517	72.7x10 ⁻⁸
NBS-2	0.0035	5.0	2.38577	69.6x10 ⁻⁸

2,000LBF RANGE

COMPRESSION DATA ONLY



20,000LBF RANGE

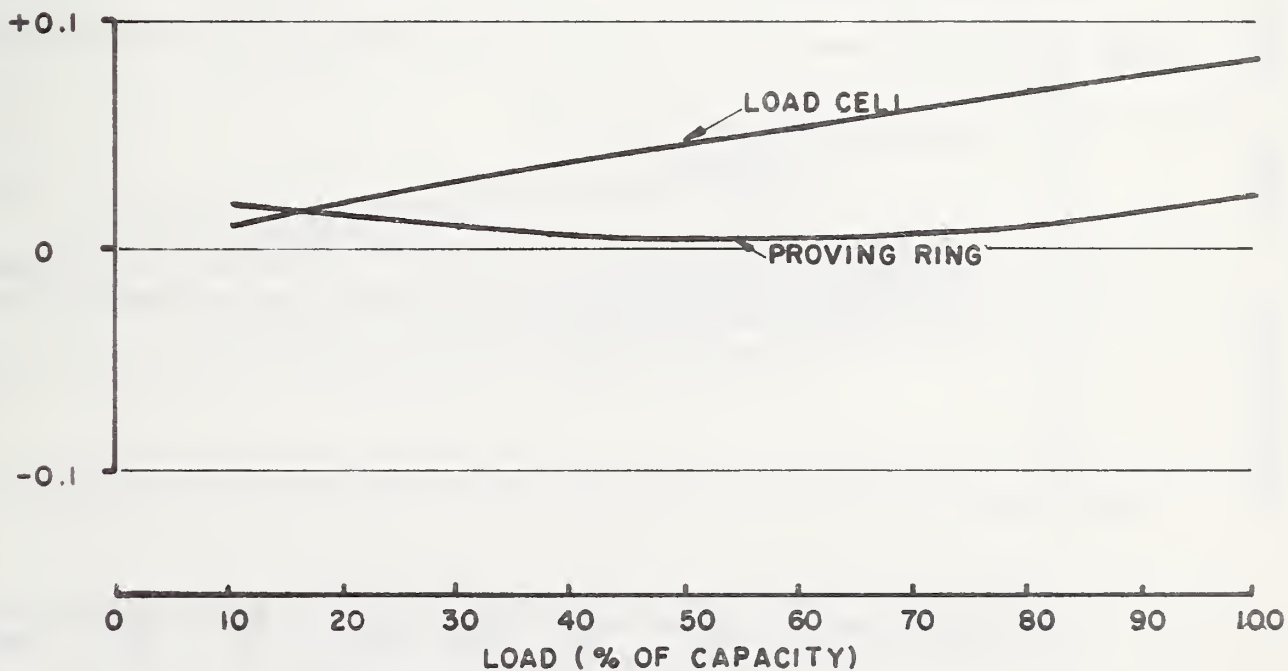


FIGURE 1 - Comparison of normalized calibration curves against First-NBS Calibration - Laboratory A

DIFFERENCE FROM FIRST-NBS CALIBRATION (% OF CAPACITY)

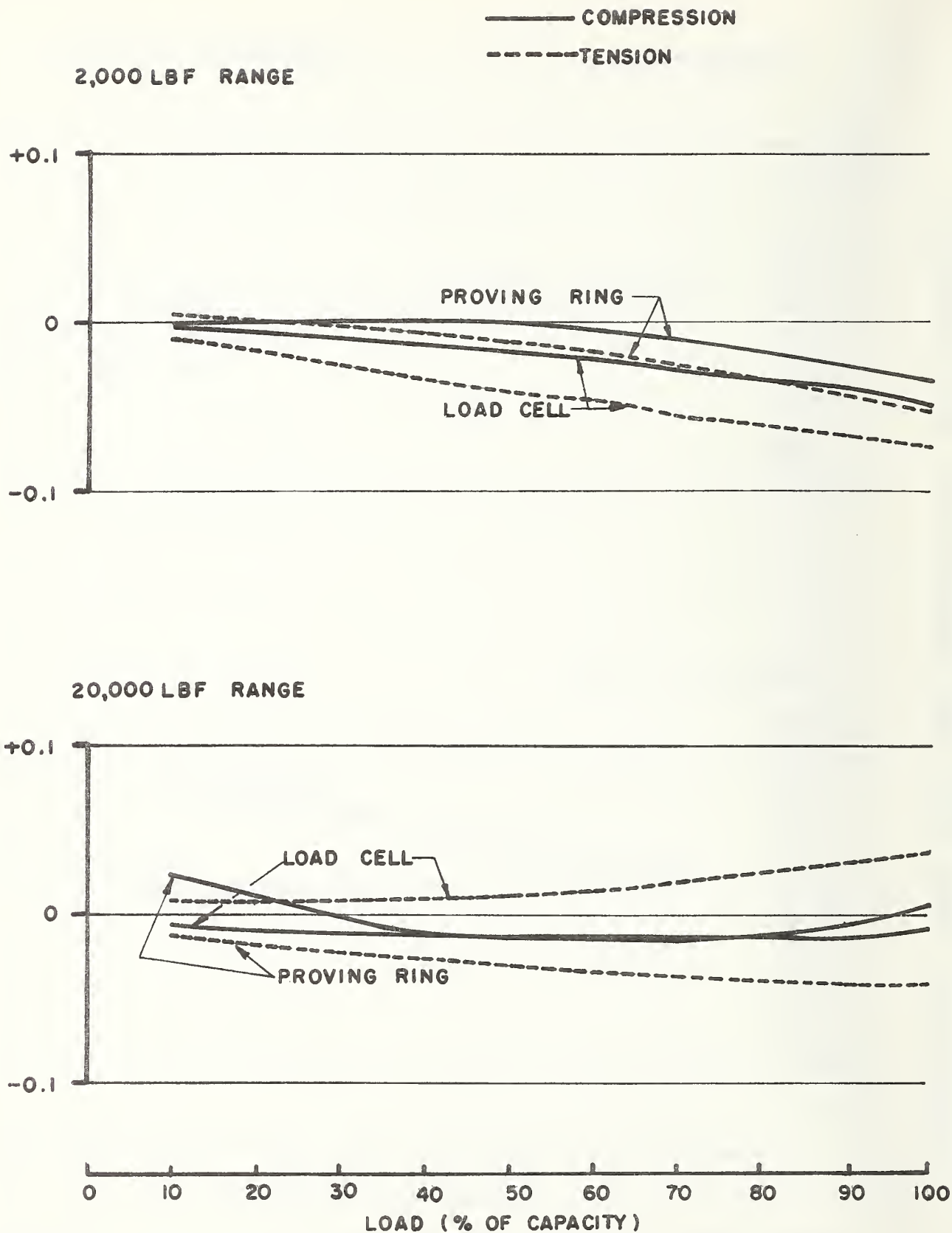


FIGURE 2 - Comparison of normalized calibration curves against First-NBS Calibration - Laboratory B

DIFFERENCE FROM FIRST-NBS CALIBRATION (% OF CAPACITY)

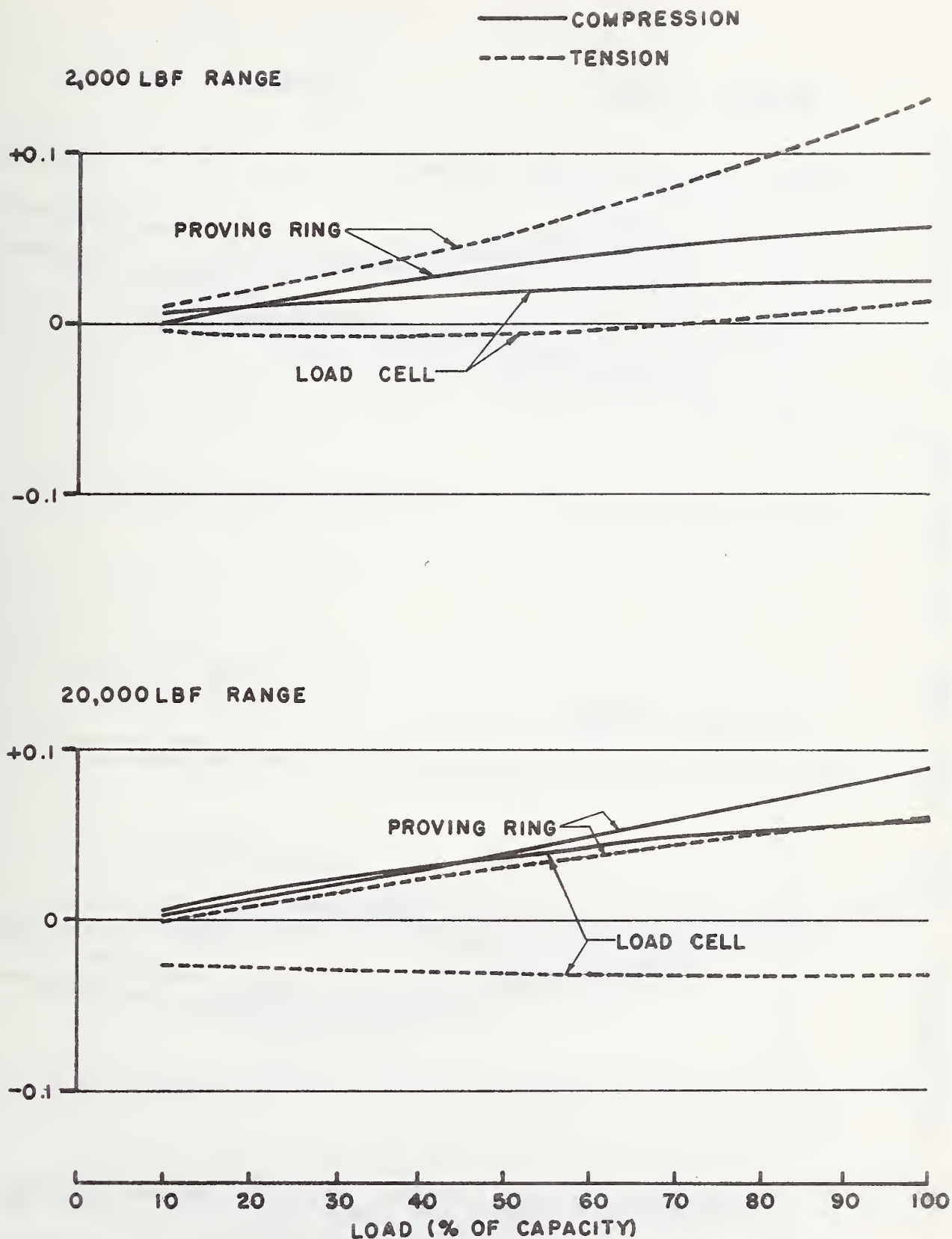


FIGURE 3 - Comparison of normalized calibration curves against First-NBS Calibration - Laboratory C

DIFFERENCE FROM FIRST-NBS CALIBRATION (% OF CAPACITY)

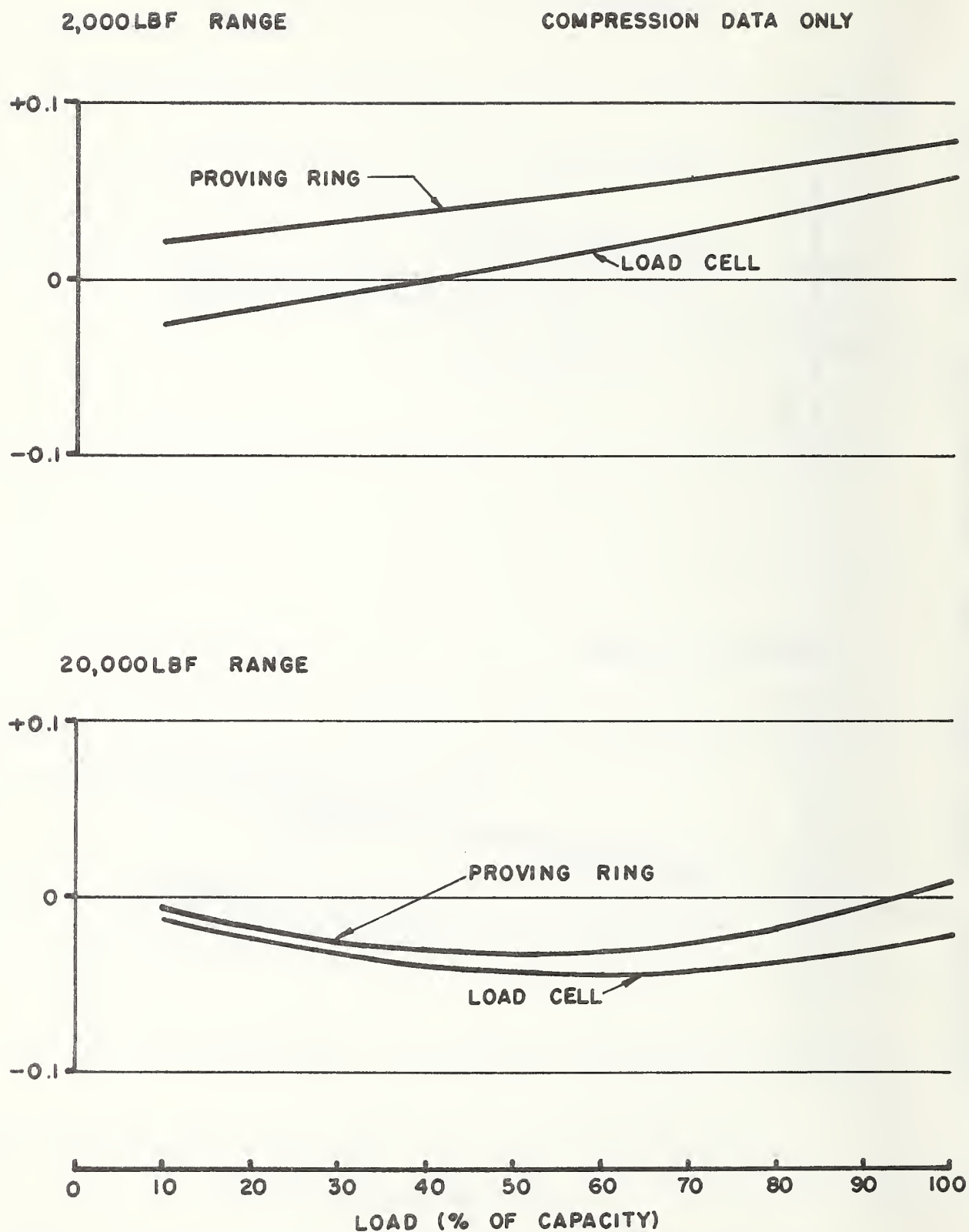


FIGURE 4 - Comparison of normalized calibration curves against First-NBS Calibration - Laboratory D

DIFFERENCE FROM FIRST-NBS CALIBRATION (% OF CAPACITY)

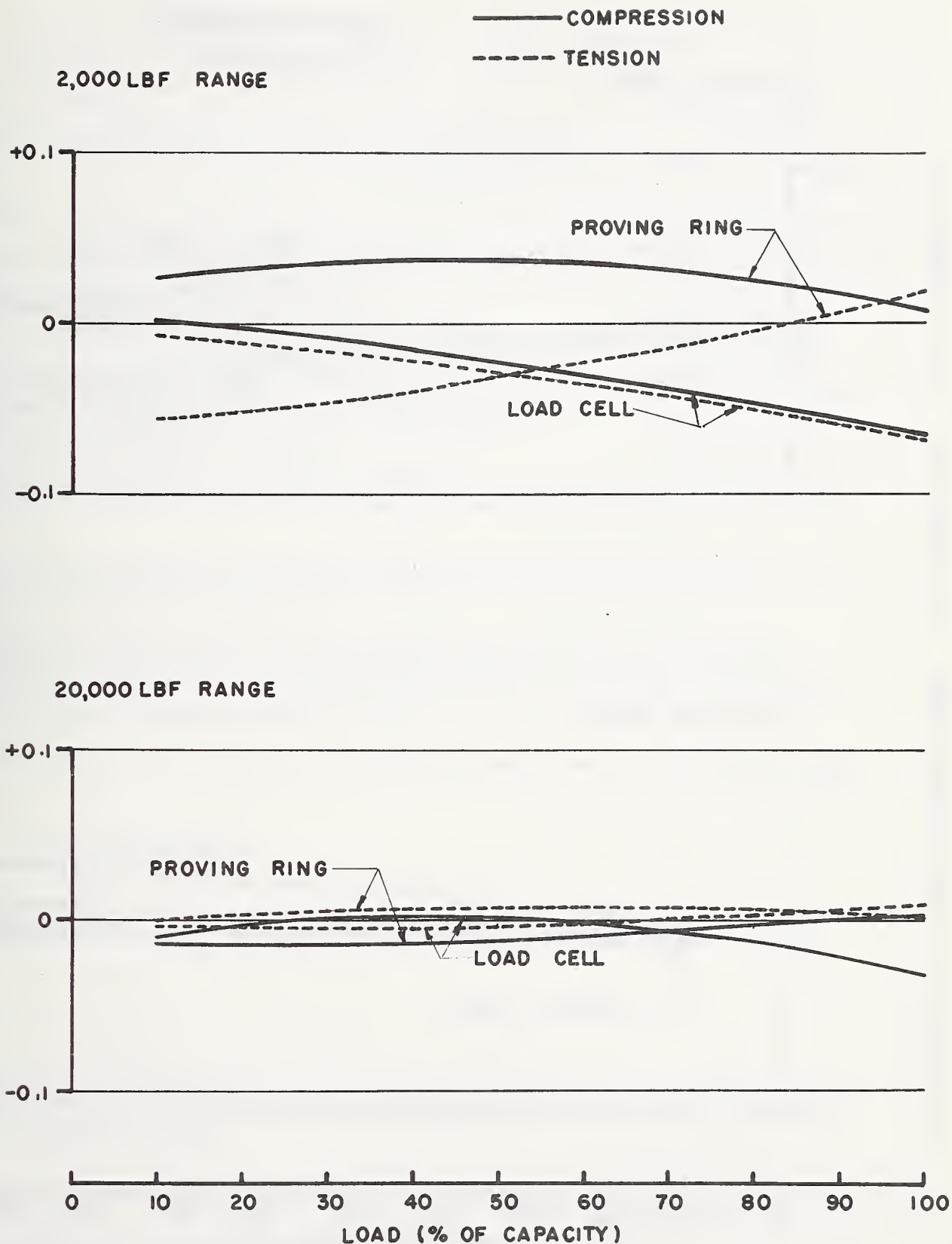


FIGURE 5 - Comparison of normalized calibration curves against First-NBS Calibration - Laboratory E

DIFFERENCE FROM FIRST-NBS CALIBRATION (% OF CAPACITY)

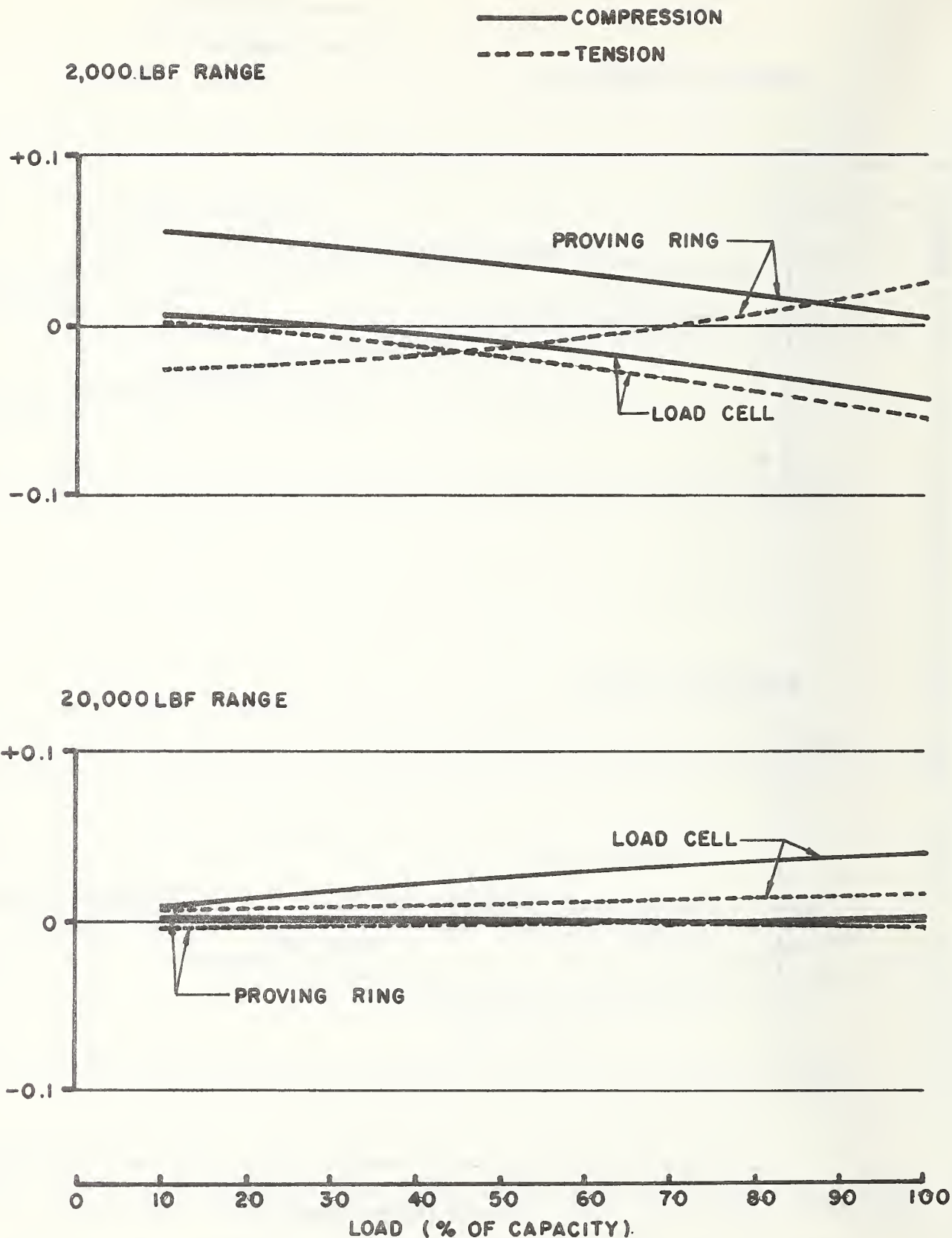


FIGURE 6 - Comparison of normalized calibration curves against First-NBS Calibration - Final NBS

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